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STIFFNESS COUPLING APPLICATION TO MODAL SYNTHESIS PROGRAM USERS GUIDE

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Nomenclature

$[m]$	=	mass matrix for substructure in $\{x\}$ physical coordinates
$[k]$	=	stiffness matrix for substructure in $\{x\}$ physical coordinates
$[\phi]$	=	matrix of substructure eigenvectors in $\{x\}$ coordinates
$[M_T]$	=	mass matrix for total structure in $\{x\}$ physical coordinates
$[K_T]$	=	stiffness matrix for total structure in $\{x\}$ physical coordinates
$[\Phi_x]$	=	matrix of eigenvectors for total structure in $\{x\}$ physical coordinates
$[M]$	=	generalized mass matrix for total structure in $\{q\}$ modal coordinates
$[K]$	=	generalized stiffness matrix for total structure in $\{q\}$ modal coordinates
$[\gamma]$	=	matrix of eigenvectors for total structure in $\{q\}$ modal coordinates
$[T]$	=	dynamic transformation matrix
$[R]$	=	transformation matrix defining the relationship of the reduced coordinates, $\{q^R\}$, to the kept coordinates $\{q^K\}$.
$\{x\}$	=	physical coordinates
$\{q\}$	=	generalized modal coordinates
Ω	=	system circular frequency (rad/sec)
ω	=	substructure circular frequency (rad/sec)
p	=	reduction circular frequency (rad/sec)
n	=	number of degrees of freedom in structure

Subscripts

i	=	refers to the i^{th} subset, term, or substructure
Δ	=	incremental mass from coupling spring
CPL	=	incremental stiffness from coupling spring
k	=	kept coordinates
r	=	reduced coordinates

Superscripts

k	=	kept coordinates
r	=	reduced coordinates
A	=	attachment coordinates
I	=	interior coordinates not attached to any other substructure
_	=	revised value
. .	=	second time derivative
ij	=	particular submatrix partition

SECTION 1

INTRODUCTION

This document describes a Fortran IV computer program used to perform modal synthesis of structures by stiffness coupling using the dynamic transformation method. The program has been named SCAMP (Stiffness Coupling Approach Modal-Synthesis Program). The program begins with the entry of a substructure's physical mode shapes and eigenvalues or a substructure's mass and stiffness matrix. If the mass and stiffness matrices (100 degrees of freedom [DOF] Limit) are entered the eigen problem for the individual substructure is solved. Provisions are included for a maximum of 20 substructures which may be coupled by stiffness matrix springs (90 DOF/spring). Each substructure can have a number of DOF, except that for DOF greater than 100, vector sets having maximum row and column size of 100 have to be generated prior to entering SCAMP. The substructures are then coupled together via coupling springs, and the dynamic transformation is used to reduce the size of the eigen problem. The total number of modes treated by the program is 300 consisting of 100 kept coordinates (maximum eigen value size) and 200 coordinates reduced by the dynamic transformation. For user flexibility, five major entry points have been included with restarting capabilities in SCAMP. Tiering can also be used with SCAMP. The assembled solution can be identified as a substructure and added to other substructures if desired. This procedure can be repeated indefinitely but care has to be exercised on the conditioning of the system mode shapes and frequencies.

Input data for SCAMP is accomplished mainly by the "READ" FORMA subroutine. Output data to be saved for re-starting SCAMP is written by special subroutines. Files containing data should be copied to an output data tape (s). Modes and frequencies for the coupled structure are output on a user specified file (or tape) and can be read using the "READ" subroutine.

SECTION 2

THEORETICAL DISCUSSION

2.1 BASIC THEORY FOR STIFFNESS COUPLING

The stiffness coupling method of modal synthesis assembles the complete structure in the same manner as the displacement method for structural analysis. The total structure may be represented by a number of substructures connected through flexible links. Each substructure is analyzed without the flexible links to determine the component vibration modes with free attachment coordinates. The flexible links are represented by a stiffness matrix relating the interface forces from one set of substructure attachment coordinates to another.

The method of substructuring for stiffness coupling may best be illustrated by considering a total structure consisting of only two substructures. The general undamped equation of motion for the ith substructure in terms of its mass matrix, $[m_i]$, and stiffness matrix, $[k_i]$, is given by

$$[m_i]\{\ddot{x}_i\} + [k_i]\{x_i\} = 0 \tag{1}$$

in which the coordinates $\{x_i\}$ describe physical motions of the mass points. Each substructure has two sets of coordinates which will be referred to as attachment coordinates, $\{x_i^A\}$, and internal coordinates, $\{x_i^I\}$. The attachment coordinates are those degrees of freedom (DOF) which are connected to another substructure via a stiffness matrix or coupling spring. The internal coordinates are those DOF which are not connected to any other substructure. It is important to note that for stiffness coupling the coordinates belonging to one particular substructure are not common to any other. If n_i represents the size of the ith substructure and n the size of the total structure comprised of r substructures, then n will be given by

$$n = \sum_{i=1}^{\hat{n}} n_i \tag{2}$$

Having defined two sets of coordinates for each substructure, Eq. (1) may be written in partitioned form as

$$\underset{n_i \times n_i}{\left[\begin{array}{c|c} m_i^{AA} & m_i^{AI} \\ \hline m_i^{IA} & m_i^{II} \end{array}\right]} \underset{n_i \times 1}{\left\{\begin{array}{c} \ddot{x}_i^A \\ \hline \ddot{x}_i^I \end{array}\right\}} + \underset{n_i \times n_i}{\left[\begin{array}{c|c} k_i^{AA} & k_i^{AI} \\ \hline k_i^{IA} & k_i^{II} \end{array}\right]} \underset{n_i \times 1}{\left\{\begin{array}{c} x_i^A \\ \hline x_i^I \end{array}\right\}} = 0 \tag{3}$$

Now consider the total structure to be described by a mass matrix, $[M_T]$, and a stiffness matrix $[K_T]$, such that

$$\underset{n \times n}{[M_T]} \underset{n \times 1}{\{\ddot{x}_T\}} + \underset{n \times n}{[K_T]} \underset{n \times 1}{\{x_T\}} = 0 \tag{4}$$

where

$$\begin{array}{l} \underset{n \times n}{[M_T]} = \begin{array}{cc} \left[\begin{array}{c|c} M_T^{11} & 0 \\ \hline 0 & M_T^{22} \end{array}\right] & \begin{array}{c} n_1 \\ n_2 \end{array} \end{array} \\ \\ \underset{n \times n}{[K_T]} = \begin{array}{cc} \left[\begin{array}{c|c} K_T^{11} & K_T^{12} \\ \hline K_T^{21} & K_T^{22} \end{array}\right] & \begin{array}{c} n_1 \\ n_2 \end{array} \end{array} \\ \\ \underset{n \times 1}{\{x_T\}} = \begin{array}{cc} \left\{\begin{array}{c} x_1 \\ \hline x_2 \end{array}\right\} & \begin{array}{c} n_1 \\ n_2 \end{array} \end{array} \end{array} \tag{5}$$

If we describe the connecting structure between $\{x_1^A\}$ and $\{x_2^A\}$ by a mass matrix, $[m_\Delta]$, where

$$\underset{(n_1^A+n_2^A)\times(n_1^A+n_2^A)}{[m_\Delta]} = \begin{array}{cc} \left[\begin{array}{c|c} m_{\Delta_1} & 0 \\ \hline 0 & m_{\Delta_2} \end{array}\right] & \begin{array}{c} n_1^A \\ n_2^A \end{array} \\ \begin{array}{cc} n_1^A & n_2^A \end{array} & \end{array} \tag{6}$$

and a stiffness matrix $[k_{CPL}]$, relating the nodal force, $\{F_i^a\}$, to $\{x_i^a\}$ by the equation

$$\underset{(n_1^A+n_2^A)\times 1}{\left\{\begin{array}{c} F_1^A \\ \hline F_2^A \end{array}\right\}} = \begin{array}{c} \left[\begin{array}{c|c} k_{CPL}^{11} & k_{CPL}^{12} \\ \hline k_{CPL}^{21} & k_{CPL}^{22} \end{array}\right] \\ \begin{array}{cc} n_1^A & n_2^A \end{array} \end{array} \left\{\begin{array}{c} x_1^A \\ \hline x_2^A \end{array}\right\} \begin{array}{c} n_1^A \\ n_2^A \end{array} \tag{7}$$

Then $[M_T]$ and $[K_T]$ may be written in partitioned form using the submatrices defined by Eqs. (3), (6) and (7):

$$\underset{n\times n}{[M_T]} = \begin{array}{cc} \left[\begin{array}{c|c|c|c} m_1^{AA}+m_{\Delta_1} & m_1^{AI} & 0 & 0 \\ \hline m_1^{IA} & m_1^{II} & 0 & 0 \\ \hline 0 & 0 & m_2^{AA}+m_{\Delta_2} & m_2^{AI} \\ \hline 0 & 0 & m_2^{IA} & m_2^{II} \end{array}\right] & \begin{array}{c} n_1^A \\ n_1^I \\ n_2^A \\ n_2^I \end{array} \\ \begin{array}{cc} \underbrace{n_1^A \quad\quad n_1^I}_{n_1} & \underbrace{n_2^A \quad\quad n_2^I}_{n_2} \end{array} & \end{array} \tag{8a}$$

$$\underset{n\times n}{[K_T]} = \begin{array}{cc} \left[\begin{array}{c|c|c|c} k_1^{AA}+k_{CPL}^{11} & k_1^{AI} & k_{CPL}^{12} & 0 \\ \hline k_1^{IA} & k_1^{II} & 0 & 0 \\ \hline k_{CPL}^{21} & 0 & k_2^{AA}+k_{CPL}^{22} & k_2^{AI} \\ \hline 0 & 0 & k_2^{IA} & k_2^{II} \end{array}\right] & \begin{array}{c} n_1^A \\ n_1^I \\ n_2^A \\ n_2^I \end{array} \\ \underbrace{n_1^A \qquad n_1^I}_{n_1} \qquad \underbrace{n_2^A \qquad n_2^I}_{n_2} & \end{array} \tag{8b}$$

By defining

$$\underset{n\times n}{[M_\Delta]} = \begin{array}{cc} \left[\begin{array}{cccc} m_{\Delta 1} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & m_{\Delta 2} & 0 \\ 0 & 0 & 0 & 0 \end{array}\right] & \begin{array}{c} n_1^A \\ n_1^I \\ n_2^A \\ n_2^I \end{array} \\ \underbrace{n_1^A \qquad n_1^I}_{n_1} \qquad \underbrace{n_2^A \qquad n_2^I}_{n_2} & \end{array} \tag{9a}$$

$$\underset{n\times n}{[K_{CPL}]} = \begin{array}{cc} \left[\begin{array}{cccc} k_{CPL}^{11} & 0 & k_{CPL}^{12} & 0 \\ 0 & 0 & 0 & 0 \\ k_{CPL}^{21} & 0 & k_{CPL}^{22} & 0 \\ 0 & 0 & 0 & 0 \end{array}\right] & \begin{array}{c} n_1^A \\ n_1^I \\ n_2^A \\ n_2^I \end{array} \\ \underbrace{n_1^A \qquad n_1^I}_{n_1} \qquad \underbrace{n_2^A \qquad n_2^I}_{n_2} & \end{array} \tag{9b}$$

and recognizing the partitions belong to each of the substructures, Eq. (4) may be written as

$$\left\{\underset{n\times n}{\left[\begin{array}{c|c} m_1 & 0 \\ \hline 0 & m_2 \end{array}\right]} + \underset{n\times n}{\left[M_\Delta\right]}\right\}\underset{n\times 1}{\left\{\begin{array}{c} \ddot{x}_1 \\ \hdashline \ddot{x}_2 \end{array}\right\}} + \left\{\underset{n\times n}{\left[\begin{array}{c|c} k_1 & 0 \\ \hline 0 & k_2 \end{array}\right]} + \underset{n\times n}{\left[K_{CPL}\right]}\right\}\underset{n\times 1}{\left\{\begin{array}{c} x_1 \\ \hdashline x_2 \end{array}\right\}} = 0 \tag{10}$$

For each substructure defined by Eq. (1), a set of eigenvalues, $\left[\diagdown \omega_i^2 \diagdown\right]$, and a set of mass normalized eigenvectors, $[\phi_i]$, can be obtained such that

$$\underset{n_i\times n_i}{[\phi_i]^T}\underset{n_i\times n_i}{[m_i]}[\phi_i] = \underset{n_i\times n_i}{[I]} \tag{11a}$$

$$\underset{n_i\times n_i}{[\phi_i]^T}\underset{n_i\times n_i}{[k_i]}[\phi_i] = \underset{n_i\times n_i}{\left[\diagdown \omega_i^2 \diagdown\right]} \tag{11b}$$

Using the results from Eq. (11), we can now express Eq. (10) in terms of a set of generalized modal coordinates, $\{q\}$. The coordinate transformation is given by

$$\underset{n\times 1}{\{x\}} = \underset{n\times n}{[\phi]}\underset{n\times 1}{\{q\}} \tag{12}$$

where

$$\underset{n\times 1}{\{x\}} = \underset{n\times 1}{\left\{\begin{array}{c} x_1 \\ \hdashline x_2 \end{array}\right\}} \qquad \underset{n\times 1}{\{q\}} = \underset{n\times 1}{\left\{\begin{array}{c} q_1 \\ \hdashline q_2 \end{array}\right\}} \tag{13a}$$

$$\underset{n\times n}{[\phi]} = \underset{n\times n}{\left[\begin{array}{c|c} \phi_1 & 0 \\ \hline 0 & \phi_2 \end{array}\right]} \tag{13b}$$

Substituting the transformation for $\{x\}$ into Eq. (10) and premultiplying by $[\phi]^T$ yields

$$\left\{\underset{n\times n}{[I]} + \underset{n\times n}{[\phi]^T[M_\Delta][\phi]}\right\}\underset{n\times 1}{\{\ddot{q}\}} + \left\{\underset{n\times n}{\left[\begin{array}{c|c} \diagdown\omega_1^2\diagdown & 0 \\ \hline 0 & \diagdown\omega_2^2\diagdown \end{array}\right]} + \underset{n\times n}{[\phi]^T[K_{CPL}][\phi]}\right\}\underset{n\times 1}{\{q\}} = 0 \tag{14}$$

Solution of Eq. (14) will result in a set of eigenvalues, $\lceil \Omega^2 \rfloor$, and their corresponding eigenvectors, $[\gamma]$. Because of the similarity transformation used to obtain Eq. (14) from Eq. (10), the eigenvalues of Eq. (10) will be equal to those of Eq. (14) and the corresponding eigenvectors, $[\phi_x]$, of Eq. (10) will be given by

$$\underset{n \times n}{[\phi_x]} = \underset{n \times n}{[\phi]}\,\underset{n \times n}{[\gamma]} \tag{15}$$

Eq. (14) represents the most general form of the equation of motion for stiffness coupling. This equation is generally solved by partitioning the {q} coordinates into two groups, kept and truncated. The truncated coordinates correspond to the high frequency substructure modes and are completely omitted from the equation of motion. Those degrees of freedom remaining, the partitioned set of kept coordinates, determine the final reduced size of the eigenvalue problem to be solved.

The general form of Eq. (14) may be simplified further by including the correct $m_{\Delta i}$ partitions from Eq. (6) in each corresponding $[m_i]$ at the substructure level. This is reasonable because we are assuming that there is no inertial coupling between substructures. This will result in $[M_\Delta] = 0$ and Eq. (14) reduces to

$$\underset{n \times n}{[I]}\,\underset{n \times 1}{\{\ddot{\gamma}\}} + \underset{n \times n}{[K]}\,\underset{n \times 1}{\{\gamma\}} = 0 \tag{16}$$

where

$$\underset{n \times n}{[K]} = \underset{n \times n}{\begin{bmatrix} \lceil \omega_1^2 \rfloor & 0 \\ 0 & \lceil \omega_2^2 \rfloor \end{bmatrix}} + \underset{n \times n}{[\phi]^T}\,\underset{n \times n}{[K_{CPL}]}\,\underset{n \times n}{[\phi]} \tag{17}$$

After solving for the ω_i's and ϕ_i's, the only lengthy calculation left to be performed in order to obtain Eq. (16) is the matrix triple-product involving $[K_{CPL}]$. If we partition each $[\phi_i]$ row-wise in terms of its n_i^A and n_i^I coordinates such that

$$\underset{n_i \times n_i}{[\phi_i]} = \begin{array}{c} \left[\begin{array}{c} \phi_i^A \\ \hline \phi_i^I \end{array}\right] \\ n \end{array} \begin{array}{c} n_i^A \\ n_i^I \end{array} \tag{18}$$

Eq. (13b) can be written as

$$\underset{n \times n}{[\phi]} = \begin{array}{c} \left[\begin{array}{cc} \phi_1^A & 0 \\ \phi_1^I & 0 \\ 0 & \phi_2^A \\ 0 & \phi_2^I \end{array}\right] \\ \begin{array}{cc} n_1 & n_2 \end{array} \end{array} \begin{array}{c} n_1^A \\ n_1^I \\ n_2^A \\ n_2^I \end{array} \tag{19}$$

By forming the triple product $[\phi]^T\,[K_{CPL}]\,[\phi]$ using Eqs. (9b) and (19) and re-factoring the result in terms of the matrix partitions, the resultant form of the triple product may be expressed as

$$[\phi^A]^T\,[k_{CPL}]\,[\phi^A] \tag{20a}$$

where

$$\underset{(n_1^A+n_2^A)\times n}{[\phi^A]} = \begin{array}{c} \left[\begin{array}{c|c} \phi_1^A & 0 \\ \hline 0 & \phi_2^A \end{array}\right] \\ \underbrace{\begin{array}{cc} n_1 & n_2 \end{array}}_{n} \end{array} \begin{array}{c} n_1^A \\ n_2^A \end{array} \tag{20b}$$

$$\underset{(n_1^A+n_2^A)\times(n_1^A+n_2^A)}{[k_{CPL}]} = \begin{array}{c} \left[\begin{array}{c|c} k_{CPL}^{11} & k_{CPL}^{12} \\ \hline k_{CPL}^{21} & k_{CPL}^{22} \end{array}\right] \\ \begin{array}{cc} n_1^A & n_2^A \end{array} \end{array} \begin{array}{c} n_1^A \\ n_2^A \end{array} \tag{20c}$$

and the final form of [K] in Eq. (17) may be expressed as

$$\underset{n \times n}{[K]} = \underset{n \times n}{\left[\begin{array}{c|c} \omega_1^2 & 0 \\ \hline 0 & \omega_2^2 \end{array}\right]} + \underset{n \times n}{[\phi^A]^T\,[k_{CPL}]\,[\phi^A]} \tag{21}$$

2.2 DYNAMIC TRANSFORMATION

As a result of omitting the higher substructure modes, the solutions from the truncated Eq. (16) will have errors introduced. The truncation errors can be greatly diminished by including the modes that would have been truncated through a dynamic transformation. Instead of truncating or omitting modes, all modes can be included through a transformation that relates the "reduced" modes not contained explicitly in the solution to the modes that are "kept." If Ω_i^2 corresponds to an exact eigenvalue of Eq. (16), the relationship between the eigenvalue and its eigenvector may be expressed in terms of the kept, $\{q^k\}$, and reduced, $\{q^r\}$, coordinates as:

$$\Omega_i^2 \underset{n\times n}{[I]} \underset{n\times 1}{\left\{\begin{array}{c} q^k \\ \hline q^r \end{array}\right\}} = \underset{n\times n}{\left[\begin{array}{c|c} K^{kk} & K^{kr} \\ \hline K^{rk} & K^{rr} \end{array}\right]} \underset{n\times 1}{\left\{\begin{array}{c} q^k \\ \hline q^r \end{array}\right\}} \tag{22}$$

where the $\{q^r\}$ corresponds to those modes previously truncated. If we designate n_k as the total number of modes kept from all the substructures and n_r as the total number of modes reduced, then

$$n = n_k + n_r \tag{23}$$

Expanding Eq. (22) into two equations for some general frequency, $p^2 = \Omega_i^2$, yeilds

$$p^2 \underset{n_k\times 1}{\{q^k\}} = \underset{n_k\times n_k}{[K^{kk}]} \underset{n_k\times 1}{\{q^k\}} + \underset{n_k\times n_r}{[K^{kr}]} \underset{n_r\times 1}{\{q^r\}} \tag{24a}$$

$$p^2 \underset{n_r\times 1}{\{q^r\}} = \underset{n_r\times n_k}{[K^{rk}]} \underset{n_k\times 1}{\{q^k\}} + \underset{n_r\times n_r}{[K^{rr}]} \underset{n_r\times 1}{\{q^r\}} \tag{24b}$$

Solving Eq. (24b) for $\{q^r\}$ in terms of $\{q^k\}$ gives

$$\underset{n_r \times 1}{\{q^r\}} = \underset{n_r \times n_k}{[R]} \underset{n_k \times 1}{\{q^k\}} \tag{25}$$

where

$$\underset{n_r \times n_k}{[R]} = - \underset{n_r \times n_r}{[K^{rr} - p^2 I]^{-1}} \underset{n_r \times n_k}{[K^{rk}]} \tag{26}$$

Using Eq. (25) for some "reduction" frequency, p, we can write

$$\underset{n \times 1}{\begin{Bmatrix} q^k \\ \hline q^r \end{Bmatrix}} = \underset{n \times 1}{\begin{Bmatrix} q^k \\ \hline R q^k \end{Bmatrix}} = \underset{n \times n_k}{\begin{bmatrix} I \\ \hline R \end{bmatrix}} \underset{n_k \times 1}{\{q^k\}} \tag{27}$$

The dynamic transformation matrix, [T], is then defined as

$$\underset{n \times n_k}{[T]} = \underset{n \times n_k}{\begin{bmatrix} I \\ \hline R \end{bmatrix}} \tag{28}$$

The reduced equation of motion is obtained directly by substituting the coordinate transformation

$$\underset{n \times 1}{\{q\}} = \underset{n \times n_k}{[T]} \underset{n_k \times 1}{\{q^k\}} \tag{29}$$

into Eq. (16) and pre-multiplying by the transpose of [T]. The reduced generalized mass and stiffness matrices can be written into the partitioned forms given by Eqs. (22) and (28).

$$\underset{n_k \times n_k}{[M^k]} = \underset{n_k \times n_k}{[I]} + \underset{n_k \times n_r}{[R]^T} \underset{n_r \times n_k}{[R]} \tag{30a}$$

$$\underset{n_k \times n_k}{[K^k]} = \underset{n_k \times n_k}{[K^{kk}]} + 2 \underset{n_k \times n_r}{[K^{kr}]} \underset{n_r \times n_k}{[R]} + \underset{n_k \times n_r}{[R]^T} \underset{n_r \times n_r}{[K^{rr}]} \underset{n_r \times n_k}{[R]} \tag{30b}$$

Conventional methods of determining eigenvalues may be applied to the reduced equation of motion to obtain a set of eigenvalues, $\lceil \Omega^{k\,2} \rfloor$, and a corresponding set of mass normalized eigenvectors, $[\gamma^k]$. From the coordinate relationship defined by Eq. (25), the reduced eigenvectors, $[\gamma^r]$, corresponding to the $\{q^r\}$ reduced coordinates are given by

$$\underset{n_r \times n_k}{[\gamma^r]} = \underset{n_r \times n_k}{[R]}\,\underset{n_k \times n_k}{[\gamma^k]} \tag{31}$$

and the physical eigenvectors for the total solution will be given by

$$\underset{n \times n_k}{[\phi_x]} = \underset{n \times n}{[\phi]}\,\underset{n \times n_k}{[\gamma^{kr}]} \tag{32}$$

where

$$[\gamma^{kr}] = \begin{array}{c} \left[\begin{array}{c} \gamma^k \\ \hdashline \gamma^r \end{array}\right] \end{array} \begin{array}{l} n_k \\ n_r \end{array} \tag{33}$$

This solution will be exact for any Ω_i^k which is the same as the reduction frequency, p , used in developing [T].

SECTION 3

PROGRAM ENTRY POINTS

In order to provide user flexibility and at the same time minimize computation of basic data changes, five major entry points have been established for SCAMP:

1. Basic substructure data entered, subsystem eigensolutions.
2. Coupling spring stiffness data entered and stiffness contributions calculated.
3. Selection of modes to be kept/reduced/truncated, generalized mass and stiffness matrices calculated.
4. P^2 value for dynamic transformation entered, eigensolution for system using the dynamic transformation.
5. Calculation of physical eigenvectors for total system, and user "print" options.

Entry into the program is accomplished by designing a specific entry point (EP). Termination of theprogram is accomplished by designating the last EP the user desires to execute.

The Figure 3-1 Flow Chart is included to show the general flow of the program.

Entry Point 1

The mass and stiffness matrices $[m_i]$, $[k_i]$, or mode shapes and eigenvalues $[\phi_i]$, $[\lambda_i]$ are read into SCAMP at EP-1. The substructures are defined in the program by a user supplied number which ranges from 1 to 20. Since each substructure is to be identified in the program by a distinct number, their input may be in any order. Each $[m_i]$, $[k_i]$ is limited to 100 DOF. If modes and frequencies are input for substructure definitions, there is no limit on the physical degrees of freedom for the substructure. However, if more than 100 physical DOF are used, the matrix of

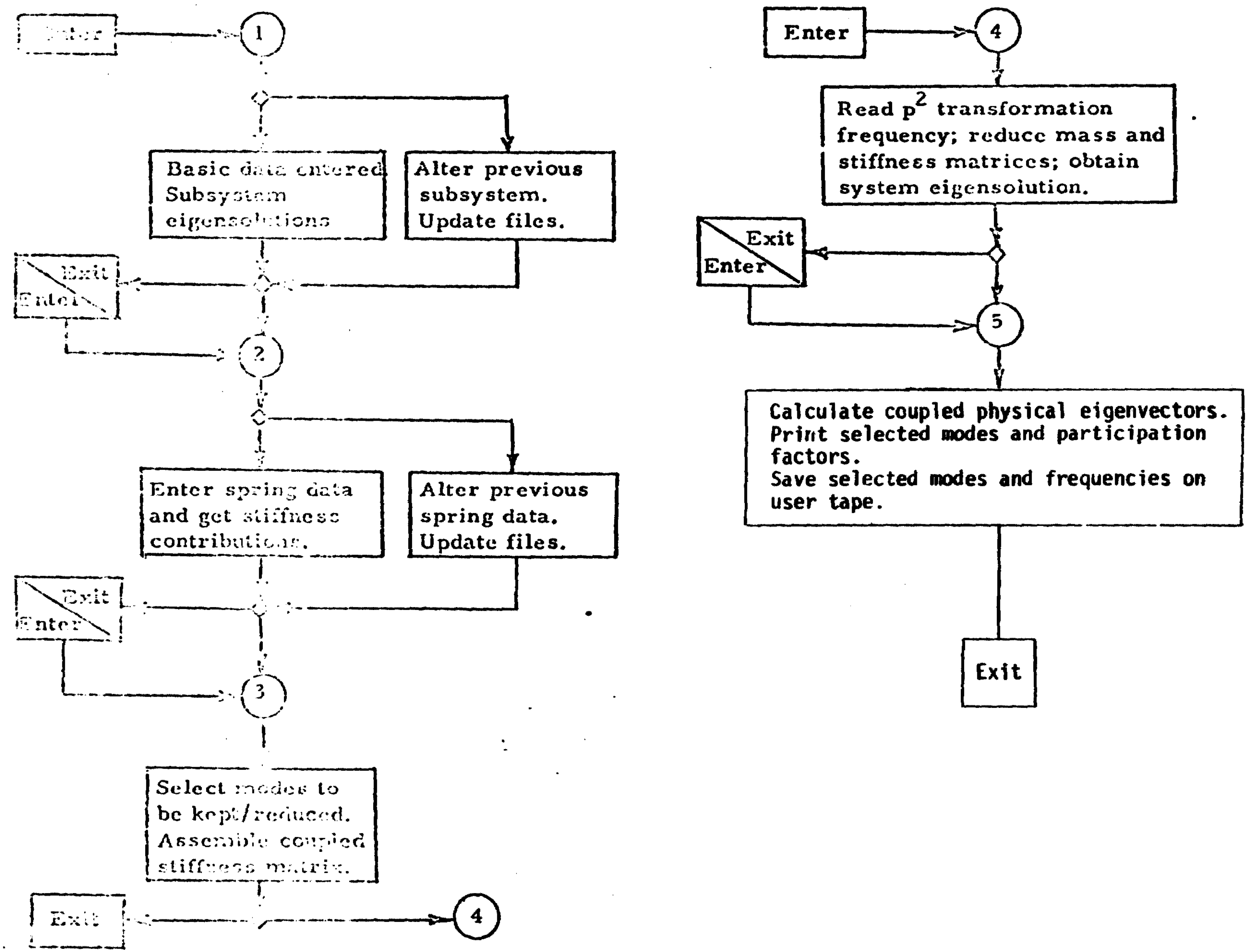


Figure 3-1. Program Flow Chart

Entry Point 3

At this EP, the user specifies which modes are to be kept and reduced. The input matrix IV defines how many modes are kept and reduced for all of the substructures. The elements are read in groups of three where the first element corresponds to some substructure identification number "ISUB", the second element the number of modes to be "Kept" for ISUB, and third element the number of modes to be "reduced" for ISUB. All other modes will be truncated. The restrictions for the total kept and reduced modes are given by

$$\sum_{i=1}^{maxsub} KEEP\ (1,\ i) \leq 100$$

$$\sum_{i=1}^{maxsub} KEEP\ (2,\ i) \leq 200$$

The generalized stiffness matrix is then assembled in its kept and reduced partitions. Only the ISUB's specified by IV will be coupled together even though there may be several more substructures and springs residing in the basic data set.

Entry Point 4

The reduction frequency, p, is entered at EP-4 (where p2 = LAMDAØ), and the dynamic transformation is applied to obtain the reduced mass and stiffness matrices. The eigenvalues for the coupled substructures are now obtained.

Entry Point 5

This entry point calculates the coupled physical eigenvectors which are printed in substructure groups. They are printed in ascending order from the originally assigned substructure number. The substructure partitions, upon output, are resequenced from one to some number "m". This facilitates re-starting SCAMP with the coupled system as a substructure having "m" partitioned physical degrees of freedom. The user must specify how many modes are to be printed by specifying the first and last mode number of the group of modes desired. Considerable computer time may be saved by printing a few of the modes. The user may desire to re-enter the program to select more modes. Also participation factors can be printed out by specifying the first and last mode number of the modes desired. Minimum values for these participation factors can be specified. Absolute values less than this will be set equal to zero and not printed. An output tape option exists which specifies the number of modes and frequencies to be put on an output user tape. The tape will contain coupled eigenvalues, frequencies in Rad/Sec, frequencies in Hz, and eigenvectors and can be read by the "read" subroutine.

SECTION 4

INPUT/OUTPUT DATA

4.1 INPUT DATA

This section describes the necessary input data required to execute SCAMP and is ordered by entry points. The data cards and the variables appearing on them are listed in sequential order with the input format or FORMA subroutine specified. The definitions for the variables specified on the cards are given to clarify their meaning. Variables followed by A.V. (Assigned Value) specifies that this particular variable has been pre-assigned a specific given value. If the A.V. specifies the desired user option, the user may delete defining the variable on the input list.

Explanation for "READ" formatted data given at end of input data section.

Input Data for Starting Program - Entry Point 0

Card Number	Input Data	Format
1	IRUN, UNAME, N1, T1	(A6, 4X, 3A6, 2X, I2, A6)
2	TITLE1	(12A6)
3	TITLE2	(12A6)
4	IENTR, IEXIT, IFIRST, FØD	$ ENTR

Definitions

IRUN	=	Run Number
UNAME	=	User's Name
N1	=	Write-Tape-No. (Eg, 21). If coupled modes and eigenvalues are to be output on an uninitialized tape. The Write-Tape No. must be specified here to initialize the tape. Leave blank for no tape initialization.
T1	=	Write-Tape-ID(EG, T12345). Leave blank if N1 not specified.
TITLE1	=	First Title
TITLE2	=	Second Title
$ ENTR	=	Namelist for Card 4 Input

IENTR = Entry Point (EP) for entering SCAMP. There are 5 EP's in all defined by the integers from 1 to 5.

IEXIT = Exit Point for terminating SCAMP. The exit points are identical to the entry points with program termination occurring after the execution of the EP specified by IEXIT. The program returns to Card 1 above. If IRUN equals the literal "STOP", the program terminates.

IFIRST = 0 (A.V.)*, denotes that SCAMP has been executed before and a restart tape containing previously generated data will be used.

= 1, required for entering a new problem into SCAMP for the first time.

FØD = 1.E-16 (A.V.), final off-diagonal value for diagonalizing a symmetric matrix using the method of Jacobi.

*The Assigned Value (A.V.) given by SCAMP. If the A.V. specifies the correct option, the user may delete the variable from the input list.

Entry Point 1

Card Number	Input Data	Format
1	ISUB, NMØDES, KEPMØD(2), MASSD, MASSWT, IALTER, MØDES, IRIGID, IRØT, NSUBS, IEND	SENTR1
*2	DIRCØS (3 x 3)	READ
*3a	MASS (NXN) or (1XN)	READ
*4a	STIFF (NXN)	READ
*3b	LAMBDA (1XM)	READ
*4b	PHY [NSUBS*(NXM)]	READ

N.B. Card 1 with IEND = 1 is the last card for substructure input.

Definitions

$ENTR1 = NAMELIST for Card 1 Input.

ISUB = Substructure identification number which ranges from 1 to 20. Each substructure must be identified by a different number.

NMØDES = The number of degrees of freedom for the mass and stiffness matrices of substructure "ISUB". If physical modes are to be read, NMODES equals the number of modes of "ISUB". ($NMODES_{max}$ = 100)

KEPMØD(1)	=	NMØDES (A.V.), number of modes to be used by SCAMP for substructure representation. Values less than NMODES will truncate the highest NMØDES-KEPMOD(1) substructure's modes.
KEPMØD(2)	=	NMØDES (A.V.), number of modes to be printed.
	=	-1, deletes printing of substructure modes.
MASSD	=	1 (A.V.), diagonal mass matrix option where the diagonal mass is a 1XNMØDES vector.
	=	0, denotes generalized mass matrix option (NMØDES x NMØDES)
MASSWT	=	1 (A.V.), weight matrix to be read instead of mass
	=	0, mass matrix option
IALTER	=	0, (A.V.), alter option. The current "ISUB" is a new substructure being added to the basic data set.
	=	1, the current "ISUB" has been read into SCAMP previously. This option will replace the "old" ISUB with new data.
MØDES	=	0 (A.V.), option for entering substructure mass and stiffness matrices
	=	1, option for entering substructure eigenvalues and eigenvectors. Options referring to mass and stiffness data are ignored.
IRIGID	=	0 (A.V.), use eigenvalues as caluated or read into SCAMP.
	=	NR, zero-out first NR eigenvalues before saving on tape.
IRØT	=	0 (A.V.), do not rotate substructure
	=	1, rotate substructure
	=	-1, rotate substructure and print un-rotated eigenvectors. KEPMOD(2) = -1 suppresses all eigenvector printing.
NSUBS	=	1 (A.V.), number of eigenvector sets within a substructure to be read in under MODES=1 option for substructure "ISUB". Maximum row and column size for any one vector set is 100. There is no limit for NSUBS.
IEND	=	0 (A.V.), optional end-of-data card. Program continually returns to Card 1 until user specifies IEND = 1$. Cards 2 through 4 are then skipped and EP-1 terminated.
DIRCØS	=	Input direction cosines matrix (3X3). Required only when IRØT.NE.0. Total number of substructure DOF's must be divisible by 3 and ordered for rotation in order to exercise this option.
MASS	=	Input mass matrix for "ISUB" (NXN) or (1XN)

STIFF = Input stiffness matrix for "ISUB" (NXN)

LAMBDA = Input eigenvalues for "ISUB" (1XM)

PHY = Input eigenvectors for "ISUB" (NXM)

(M_{MAX} = N_{MAX} = 100)

Entry Point 2

Card Number	Input Data	Format
1	IJSUBS (2), NACØRD(2), IALTER, IEND	$ENTR2
2	NASUB, NA (NC)	$ENTR2A
3	NASUB, NA (NC)	$ENTR2B
4	KCPL (MXM)	READ

Definitions

$ENTR2 = NAMELIST for Card 1 Input.

IJSUBS(1) = First "ISUB" coupled by KCPL. DOF for this substructure will be located in the $KCPL_{11}$ partition of KCPL. "ISUB" is the user specified substructure number.

IJSUBS(2) = Second "ISUB" coupled by KCPL. DOF for this substructure will be located in the $KCPL_{22}$ partition of KCPL.

NACORD(1) = Total number of attachment DOF's in IJSUBS(1).

NACORD(2) = Total number of attachment DOF's in IJSUBS(2).

IALTER = 0 (A.V.), alter option. The current KCPL defined by IJSUBS is a new coupling spring being added to the basic data set.

= 1, the current KCPL has been read into SCAMP previously. This option will replace the "old" KCPL with new data.

IEND = 0 (A.V.), optional end-of-data card. Program continually returns to Card 1 until user specifies IEND = 1$. Cards 2 through 4 are then skipped and EP-2 terminated.

$ENTR2A,B = NAMELIST Input for Cards 2 and 3.

NASUB = Number of coordinates (elements) specified in "NA" vector.

KEPMØD(1) = NMØDES (A.V.), number of modes to be used by SCAMP for substructure representation. Values less than NMODES will truncate the highest NMØDES-KEPMOD(1) substructure's modes.

KEPMØD(2) = NMØDES (A.V.), number of modes to be printed.

= -1, deletes printing of substructure modes.

MASSD = 1 (A.V.), diagonal mass matrix option where the diagonal mass is a 1XNMØDES vector.

= 0, denotes generalized mass matrix option (NMØDES x NMØDES)

MASSWT = 1 (A.V.), weight matrix to be read instead of mass

= 0, mass matrix option

IALTER = 0, (A.V.), alter option. The current "ISUB" is a new substructure being added to the basic data set.

= 1, the current "ISUB" has been read into SCAMP previously. This option will replace the "old" ISUB with new data.

MØDES = 0 (A.V.), option for entering substructure mass and stiffness matrices

= 1, option for entering substructure eigenvalues and eigenvectors. Options referring to mass and stiffness data are ignored.

IRIGID = 0 (A.V.), use eigenvalues as caluated or read into SCAMP.

= NR, zero-out first NR eigenvalues before saving on tape.

IRØT = 0 (A.V.), do not rotate substructure

= 1, rotate substructure

= -1, rotate substructure and print un-rotated eigenvectors. KEPMOD(2) = -1 suppresses all eigenvector printing.

NSUBS = 1 (A.V.), number of eigenvector sets within a substructure to be read in under MODES=1 option for substructure "ISUB". Maximum row and column size for any one vector set is 100. There is no limit for NSUBS.

IEND = 0 (A.V.), optional end-of-data card. Program continually returns to Card 1 until user specifies IEND = 1S. Cards 2 through 4 are then skipped and EP-1 terminated.

DIRCØS = Input direction cosines matrix (3X3). Required only when IRØT.NE.0. Total number of substructure DOF's must be divisible by 3 and ordered for rotation in order to exercise this option.

MASS = Input mass matrix for "ISUB" (NXN) or (1XN)

STIFF	=	Input stiffness matrix for "ISUB" (NXN)
LAMBDA	=	Input eigenvalues for "ISUB" (1XM)
PHY	=	Input eigenvectors for "ISUB" (NXM)
		($M_{MAX} = N_{MAX} = 100$)

Entry Point 2

Card Number	Input Data	Format
1	IJSUBS (2), NACØRD(2), IALTER, IEND	$ENTR2
2	NASUB, NA (NC)	$ENTR2A
3	NASUB, NA (NC)	$ENTR2B
4	KCPL (MXM)	READ

Definitions

$ENTR2	=	NAMELIST for Card 1 Input.
IJSUBS(1)	=	First "ISUB" coupled by KCPL. DOF for this substructure will be located in the $KCPL_{11}$ partition of KCPL. "ISUB" is the user specified substructure number.
IJSUBS(2)	=	Second "ISUB" coupled by KCPL. DOF for this substructure will be located in the $KCPL_{22}$ partition of KCPL.
NACORD(1)	=	Total number of attachment DOF's in IJSUBS(1).
NACORD(2)	=	Total number of attachment DOF's in IJSUBS(2).
IALTER	=	0 (A.V.), alter option. The current KCPL defined by IJSUBS is a new coupling spring being added to the basic data set.
	=	1, the current KCPL has been read into SCAMP previously. This option will replace the "old" KCPL with new data.
IEND	=	0 (A.V.), optional end-of-data card. Program continually returns to Card 1 until user specifies IEND = 1$. Cards 2 through 4 are then skipped and EP-2 terminated.
$ENTR2A,B	=	NAMELIST Input for Cards 2 and 3.
NASUB	=	Number of coordinates (elements) specified in "NA" vector.

NA = Input vector identifying the attachment coordinate DOF's. $ENTR2A selects coordinates from substructure IJSUBS(1) and $ENTR2B selects coordinates from 1JSUBS(2). If NSUBS = 1, the first element NA(1) will be equal to 1 and the remaining elements will define all the attachment coordinates in the substructure. If NSUBS>1, all the attachment coordinates may not occur in one eigenvalue partition of the substructure. In this case NA(1) designates the eigenvalue partition number and the remaining elements define the attachment coordinates in this partition. When NA(1) is given a negative sign, the namelist is repeated in order to define attachment coordinates from another partition. A positive sign is assigned to NA(1) for the partition that completes the specification of attachment coordinates.

The part of the vector identifying the attachment coordinates is filled out according to the IDFILL* subroutine with the last element negative denoting the end of the string. The order specified by the vector must correspond to the coupling spring DOF's used to couple the two substructures together.

KCPL = Coupling spring stiffness matrix which connects only two substructures. The DOF's for the spring are in the order defined by ENTR2A and ENTR2B, respectively. (M_{MAX} = 90).

*Explanation at end of section.

Entry Point 3

Card Number	Input Data	Format
1	NK,IV	$ENTR3

Definitions

$ENTR3 = NAMELIST Input for Card 1

NK = Number of elements specified in "IV" vector

IV = Input vector defining how many modes are to be kept and reduced for all of the substructures. The elements are read in groups of three where the first element corresponds to some "ISUB", the second element to the number of modes to be "kept" for ISUB and the third element to the number of modes to be "reduced" for ISUB. Only the ISUB's specified by IV will be coupled together even though there may be several more substructures and springs residing in the basic data set. A maximum of 100 modes may be specified as "kept" and a maximum of 200 as "reduced".

Entry Point 4

Card Number	Input Data	Format
1	LAMDAØ	$ENTR4

Definitions

$ENTR4	=	NAMELIST Input for Card 1
LAMDAØ	=	p^2 value used in the dynamic transformation for reduction. Where p is the circular frequency (Rad/Sec) and λ $(=p^2)$ the eigenvalue.

Entry Point 5

Card Number	Input Data	Format
1	NMØDES, MD1, MD2, PF2, GMIN	$ENTR5
	NTAPE, KMØDES, LIST	

Definitions

$ENTR5	=	NAMELIST Input for Card 1
NMØDES	=	N(A.V.), the total number of physical eigenvectors to be calculated after coupling solution. N equals the total number of "kept" DOF.
	=	-1, do not calculate any physical modes.
MD1	=	0 (A.V.), First mode number of eigenvectors to be printed. If MD1 .EQ. 0, no modes are printed.
MD2	=	N (A.V.), last mode number of eigenvectors to be printed. (MD2 $\leq$ N)
PF1	=	0 (A.V.), first participation factor mode number to be printed. If PF1. EQ. 0, no participation factors are printed.
PF2	=	N (A.V.) last participation factor mode number to be printed. (PF2 $\leq$ N)
GMIN	=	0 (A.V.), minimum value for participation factors. Absolute values less than this will be set equal to zero and not printed. (Use WRITE Subroutine).
NTAPE	=	0 (A.V.), output DYNAMO tape containing coupled eigenvalues and eigenvectors. If NTAPE.EQ.0, no output tape is prepared. Tape will contain eigenvalues, frequencies in rad/sec, frequencies in Hz, and eigenvectors. Initialize tape, if necessary, on card 1, EP-0.
KMØDES	=	N (A.V.), total number of modes and frequencies to be output on tape. (KMODES $\leq$ N).
LIST	=	0 (A.V.), LTAPE option ignored.
	=	1, a call to LTAPE (NTAPE) is initiated.

```
      SUBROUTINE IDFILL (ID, IV, JV, NN, NKEPT)
C
C     SPECIAL ROUTINE FOR GENERATING FULL DOF IDENTIFICATION VECTORS
C     FOR INPUT TO SUBROUTINES REVSYM AND REVADD.
C     CALLS SUBROUTINE ZZBOMB
C     PROGRAMMED BY EJ KUHAR     NOVEMBER 1972
C
C          SUBROUTINE ARGUMENTS

C     ID    =   INPUT VECTOR                       SIZE (M), WHERE M.LE.NN
C     IV    =   OUTPUT VECTOR EXPANDED FROM ID     SIZE (NN)
C     JV    =   OUTPUT VECTOR ORDERED BY IV        SIZE (NN)
C     NN    =   INPUT VECTOR LENGTH FOR IV, JV
                      .GT.O FILLS FIRST NKEPT      LOCATIONS OF IV FROM ID
                      .LT.O FILLS LAST NN - NKEPT LOCATIONS OF IV FROM ID
    NKEPT =     OUTPUT NUMBER OF ELEMENTS SPECIFIED BY ID, IF NN.LT.O
                       NKEPT = ABS(NN) - NO. OF ELEMENTS SPECIFIED BY ID.
C
C**** ID VECTOR ****
C     THE ID VECTOR IS USED TO SPECIFY A PARTICULAR SEQUENCE OF INTEGERS
C     TO BE EXPANDED SEQUENTIALLY IN THE IV VECTOR. INCLUSIVE GROUPS OF
C     INTEGERS TO BE GENERATED IN ASCENDING ORDER MAY BE SPECIFIED AT ANY
C     ONE TIME BY USING THREE ELEMENTS OF ID WHERE
C     ID(I)    = N1
C     ID (I+1) = 0
C     ID (I+2) = N2    (N2. GT.N1+1)
C     THE INTEGERS FROM N1 TO N2 WILL BE SEQUENTIALLY LOADED INTO THE IV
C     MATRIX STARTING FROM THE FIRST AVAILABLE LOCATION IN IV.
C     IF THE TOTAL NUMBER OF INTEGERS SPECIFIED BY ID IS . LT . NN, THE LAST
C     ELEMENT OF ID MUST BE 'NEGATIVE'.  NKEPT WILL BE CALCULATED AND THE
C     UNSPECIFIED INTEGERS WILL BE INSERTED INTO THE REMAINING IV LOCATIONS
C
C**** IV, JV VECTORS ****
C     THE IV VECTOR WILL CONTAIN NN NON-ZERO ELEMENTS AND IS USUALLY
C     USED AS THE INPUT VECTOR 'IVEC' IN SUBROUTINE REVSYM WHICH REVISES
C     THE DOF'S TO APPEAR IN THE ORDER SPECIFIED BY IVEC.
C     THE JV VECTOR REPRESENTS THE EQUIVALENT INPUT VECTOR FOR REVADD.
```

```
      SUBROUTINE READ      (A,NR,NC,KR,KC)
C
C     READ MATRIX OF REAL NUMBERS FROM CARDS OR TAPE AND RPINT IT.  WRITE
C     MATRIX ON TAPE IF SO INDICATED (BY HAVING THE WRITE-TAPE NUMBER IN
C     COLUMNS 79-80).
C     THE EXPLANATION OF FORMATS USED BELOW IS ...
C          A - DENOTES ANY KEY PUNCH SYMBOL.  (EG, A1/*C).
C          I - DENOTES AN INTEGER NUMBER,  (EG, 436).
C          E - DENOTES A REAL NUMBER,  (EG, 24.963).
C     **** CARD INPUT ****
C     FIRST CARD   -  MATRIX NAME, NUMBER OF ROWS, NUMBER OF COLUMNS
C                     WITH A6,14,15 FORMAT.
                   -  REMARKS IN COLUMNS 16-69, A-TYPE FORMAT.
                   -  BLANK IN COL. 71 (NEW PAGE FOR TAPE WRITE PRINTOUT)
C                  -  * IN COL. 71 (SAME PAGE FOR TAPE WRITE PRINTOUT)
C                  -  $ IN COLUMN 72 FOR WRITE-TAPE INITIALIZATION.
C                  -  WRITE-TAPE CONTROL IN COLUMNS 73-78, MAY BE BLANK, OR
C                     THE WORDS REWIND OR LIST. OR (WHEN $ IN COLUMN 72)
C                     THE WRITE-TAPE-ID (EG, T1234).
C                  -  WRITE-TAPE NUMBER IN COLUMNS 79-80, (EG, 21).
C     MIDDLE CARDS
C                  -  DATA WITH FORMAT (215, 4E17)
C                  -  1-ST 15 IS THE ROW NUMBER.
C                  -  2-ND 15 IS THE COL. NUMBER OF THE NEXT E17 FIELD.
C                  -  NEXT 4E17 ARE ELEMENTS OF THE MATRIX.
C     LAST CARD    -  TEN ZEROS IN COLUMNS 1-10.
C     **** TAPE INPUT ****
C     ONE CARD     -  MATRIX NAME, ZERO OR MINUS THE LOCATION NUMBER OF MATRIX
C                     ON READ-TAPE, READ-TAPE NUMBER (IF MINUS, NO PRINTOUT).
C                     MATRIX RUN NUMBER WITH A6,14,15,A6 FORMAT.
C                  -  READ-TAPE CONTROL IN COLUMNS 22-27, MAY BE BLANK, OR THE
C                     WORDS REWIND OR LIST.
C                  -  REMARKS IN COLUMNS 28-69, A-TYPE FORMAT.
C                  -  $ IN COLUMN 72 FOR WRITE-TAPE INITIALIZATION.
C                  -  WRITE-TAPE CONTROL IN COLUMNS 73-78, MAY BE BLANK, OR
C                     THE WORDS REWIND OR LIST, OR (WHEN $ IN COLUMN 72)
C                     THE WRITE-TAPE-ID (EG, T1234).
C                  -  WRITE-TAPE NUMBER IN COLUMNS 79-80, (EG, 21).
C     CALLS FORMA SUBROUTINES INTAPE, LTAPE, PAGEWD, RTAPE, WRITE,WTAPE,ZZBCMB

C          SUBROUTINE ARGUMENTS
C     A      =    OUTPUT MATRIX READ FROM CARDS OR TAPE.
C     NR     =    OUTPUT NUMBER OF ROWS IN MATRIX A.
C     NC     =    OUTPUT NUMBER OF COLS IN MATRIX A.
C     KR     =    INPUT  ROW DIMENSION OF A IN CALLING PROGRAM.
C     KC     =    INPUT  COL DIMENSION OF A IN CALLING PROGRAM.
C
```

4.2 OUTPUT DATA

Output data is saved on a user-designated file/tape. It consists of coupled eigenvalues, frequencies in rad/sec, frequencies in Hz, and the coupled eigenvector partitions with assigned matrix names of LAMSYS, ϕMEGA, FREQ, PHYS1, PHYS2, . . . PHYSM, respectively. PHYSM is the last substructure partitioned eigenvector where "M" is the total number of substructure partitions. This data can be accessed via the "READ" subroutine.

A data listing of the user tape can be obtained by using the "LTAPE" option in EP-5.

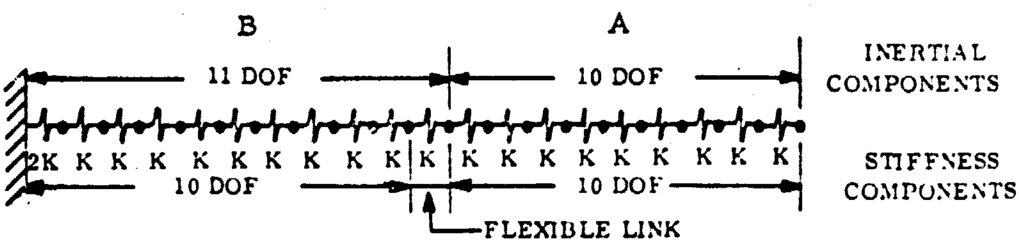
4.3 DATA FILES

Seven data files are required to execute SCAMP. These data files have been assigned the specific file codes of 11 through 17. The first five files (11-15) are used to save basic data. If the user desires to re-start SCAMP, these files must be saved on a data tape(s) after a SCAMP execution. For re-start, the user must load files 11 through 15 with the old data. Files 16 and 17 are scratch files used by SCAMP. Additional files (or tapes) may be specified by the user for data input and/or output.

APPENDIX A

SAMPLE PROBLEM

This appendix contains a sample problem using all 5 entry points of SCAMP. The sample problem consists of a 20 degree of freedom longitudinal rod model shown in the sketch below. Two substructures are used, each with 10 degrees of freedom. The output data printed by SCAMP follows a listing of the actual input data cards used to execute the program.



LONGITUDINAL ROD MODEL (20 DOF WITH 1 DOF PER NODE)

INPUT DATA DECK

```
CHK001     E J KUHAR
STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD       2 SUBSTRUCTURES
 $ENTR    IENTR=1,       IEXIT=5,      IFIRST=1$
 $ENTR1    ISUB=1,   NMODES=10,   MASSWT=0$
M1          1    10                MASS MATRIX                                          *
    1       1    1.                   1.                   1.                   1.
    1       5    1.                   1.                   1.                   1.
    1       9    1.                   1.
0000000000
K1         10    10                STIFFNESS MATRIX                                     *
    1       1    2000.                -2000.
    2       1    -2000.               4000.                -2000.
    3       2    -2000.               4000.                -2000.
    4       3    -2000.               4000.                -2000.
    5       4    -2000.               4000.                -2000.
    6       5    -2000.               4000.                -2000.
    7       6    -2000.               4000.                -2000.
    8       7    -2000.               4000.                -2000.
    9       8    -2000.               4000.                -2000.
   10       9    -2000.               6000.
0000000000
 $ENTR1    ISUB=2,   NMODES=10,   MASSWT=0$
M2          1    10                MASS MATRIX                                          *
    1       1    1.                   1.                   1.                   1.
    1       5    1.                   1.                   1.                   1.
    1       9    1.                   1.
0000000000
K2         10    10                STIFFNESS MATRIX                                     *
    1       1    2000.                -2000.
    2       1    -2000.               4000.                -2000.
    3       2    -2000.               4000.                -2000.
    4       3    -2000.               4000.                -2000.
    5       4    -2000.               4000.                -2000.
    6       5    -2000.               4000.                -2000.
    7       6    -2000.               4000.                -2000.
    8       7    -2000.               4000.                -2000.
    9       8    -2000.               4000.                -2000.
   10       9    -2000.               2000.
0000000000
 $ENTR1    IEND=1$
 $ENTR2     IJSUBS=1,2,        MACORD=1,1$
 $ENTR2A    NASUB/NA=1,-1$
 $ENTR2B    NASUB/NA=1,-1$
KCPL        2     2                COUPLING SPRING STIFFNESS MATRIX                     *
    1       1     2000.               -2000.
```

```
   2    1    -2000.              2000.
0000000000
 $ENTR2       IEND=1$
 $ENTR3    NK/IV=1,2,8,    2,2,8$
 $ENTR4      LAMDAO=0.$
 $ENTR5    MD1=1,PF1=1$
STOP
```

```
                         TIME SHEET
                ------------------------------------

                CURRENT TIME OF DAY          =    10.938212

 NAMELIST   ENTR
 IENTR =            1,   IEXIT =          5,   IFIRST=          1,
 FCU   =   0.10000000E-15,
 $ END
```

```
RUN NO. CHK001                                         DATE ( 1174                                    PAGE NO.   1
EP  1                                                 RUN BY E J KUMAR

           STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
           20 DOF LONGITUDINAL ROD      2 SUBSTRUCTURES

 NAMELIST    ENTR1
 ISUB  =              1,   NMODES=            10,
 KEPMOD(I)=
      1              10,             10,
 MASSD =              1,   MASSWT=             0,   IALTER=             0,   MODES =             0,   IRIGID=            0,
 IROT  =              0,   NSUBS =             1,   IEND  =             0,
 $ END

  CARD INPUT MATRIX M1        (   1 X  10 )               MASS MATRIX                                                  0

      1    1   1,00000000E 00   1,00000000E 00   1,00000000E 00   1,00000000E 00
      1    5   1,00000000E 00   1,00000000E 00   1,00000000E 00   1,00000000E 00
      1    9   1,00000000E 00   1,00000000E 00

  END OF READ,

  CARD INPUT MATRIX K1        (  10 X  10 )               STIFFNESS MATRIX                                             0

      1    1   2,00000000E 03  -2,00000000E 03   0,               0,
      2    1  -2,00000000E 03   4,00000000E 03  -2,00000000E 03   0,
      3    2  -2,00000000E 03   4,00000000E 03  -2,00000000E 03   0,
      4    3  -2,00000000E 03   4,00000000E 03  -2,00000000E 03   0,
      5    4  -2,00000000E 03   4,00000000E 03  -2,00000000E 03   0,
      6    5  -2,00000000E 03   4,00000000E 03  -2,00000000E 03   0,
      7    6  -2,00000000E 03   4,00000000E 03  -2,00000000E 03   0,
      8    7  -2,00000000E 03   4,00000000E 03  -2,00000000E 03   0,
      9    8  -2,00000000E 03   4,00000000E 03  -2,00000000E 03
     10    9  -2,00000000E 03   6,00000000E 03

  END OF READ,
```

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD 2 SUBSTRUCTURES

```
LAM1
(   1 X  10 )         (  2)        (  3)        (  4)        (  5)        (  6)        (  7)        (  8)        (  9)        ( 10)
1    1  4.9247E 01  4.3597E 02  1.1716E 03  2.1840E 03  3.3743E 03  4.6257E 03  5.8160E 03  6.8284E 03  7.5640E 03  7.9508E 03

OMG1
(   1 X  10 )         (  2)        (  3)        (  4)        (  5)        (  6)        (  7)        (  8)        (  9)        ( 10)
1    1  7.0176E 00  2.0800E 01  3.4220E 01  4.6734E 01  5.8088E 01  6.8013E 01  7.6262E 01  8.2634E 01  8.6971E 01  8.9167E 01

CPS1
(   1 X  10 )         (  2)        (  3)        (  4)        (  5)        (  6)        (  7)        (  8)        (  9)        ( 10)
1    1  1.1169E 00  3.3232E 00  5.4470E 00  7.4379E 00  9.2451E 00  1.0825E 01  1.2138E 01  1.3152E 01  1.3842E 01  1.4191E 01
```

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD 2 SUBSTRUCTURES

PHY1

(10 X	10)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	1	4.4583E-01	4.3486E-01	4.1317E-01	3.8131E-01	3.4006E-01	2.9044E-01	2.3367E-01	1.7114E-01	1.0440E-01	3.5088E-02
2	1	4.3486E-01	3.4006E-01	1.7114E-01	-3.5088E-02	-2.3367E-01	-3.8131E-01	-4.4583E-01	-4.1317E-01	-2.9044E-01	-1.0440E-01
3	1	4.1317E-01	1.7114E-01	-1.7114E-01	-4.1317E-01	-4.1317E-01	-1.7114E-01	1.7114E-01	4.1317E-01	4.1317E-01	1.7114E-01
4	1	3.8131E-01	-3.5088E-02	-4.1317E-01	-3.4006E-01	1.0440E-01	4.3486E-01	2.9044E-01	-1.7114E-01	-4.4583E-01	-2.3367E-01
5	1	3.4006E-01	-2.3367E-01	-4.1317E-01	1.0440E-01	4.4583E-01	3.5088E-02	-4.3486E-01	-1.7114E-01	3.8131E-01	2.9044E-01
6	1	2.9044E-01	-3.8131E-01	-1.7114E-01	4.3486E-01	3.5088E-02	-4.4583E-01	1.0440E-01	4.1317E-01	-2.3367E-01	-3.4006E-01
7	1	2.3367E-01	-4.4583E-01	1.7114E-01	2.9044E-01	-4.3486E-01	1.0440E-01	3.4006E-01	-4.1317E-01	3.5088E-02	3.8131E-01
8	1	1.7114E-01	-4.1317E-01	4.1317E-01	-1.7114E-01	-1.7114E-01	4.1317E-01	-4.1317E-01	1.7114E-01	1.7114E-01	-4.1317E-01
9	1	1.0440E-01	-2.9044E-01	4.1317E-01	-4.4583E-01	3.8131E-01	-2.3367E-01	3.5088E-02	1.7114E-01	-3.4006E-01	4.3486E-01
10	1	3.5088E-02	-1.0440E-01	1.7114E-01	-2.3367E-01	2.9044E-01	-3.4006E-01	3.8131E-01	-4.1317E-01	4.3486E-01	-4.4583E-01

```
          STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
          20 DOF LONGITUDINAL ROD      2 SUBSTRUCTURES

 NAMELIST     ENTR1
 ISUB  =               2,    NMODES=          10,
 KEPMODE(I)=
     1                10,             10,
 MASSD =               1,    MASSWT=           0,    IALTER=           0,    MODES =          0,   IRIGID=          0,
 IROT  =               0,    NSUBS =           1,    IEND   =          0,
 $ END

  CARD INPUT MATRIX M2       (   1 X  10 )              MASS MATRIX                                   0

     1   1   1.00000000E 00   1.00000000E 00   1.00000000E 00   1.00000000E 00
     1   5   1.00000000E 00   1.00000000E 00   1.00000000E 00   1.00000000E 00
     1   9   1.00000000E 00   1.00000000E 00

  END OF READ,

  CARD INPUT MATRIX K2       (  10 X  10 )              STIFFNESS MATRIX                              0

     1   1   2.00000000E 03  -2.00000000E 03   0.               0.
     2   1  -2.00000000E 03   4.00000000E 03  -2.00000000E 03   0.
     3   2  -2.00000000E 03   4.00000000E 03  -2.00000000E 03   0.
     4   3  -2.00000000E 03   4.00000000E 03  -2.00000000E 03   0.
     5   4  -2.00000000E 03   4.00000000E 03  -2.00000000E 03   0.
     6   5  -2.00000000E 03   4.00000000E 03  -2.00000000E 03   0.
     7   6  -2.00000000E 03   4.00000000E 03  -2.00000000E 03   0.
     8   7  -2.00000000E 03   4.00000000E 03  -2.00000000E 03   0.
     9   8  -2.00000000E 03   4.00000000E 03  -2.00000000E 03
    10   9  -2.00000000E 03   2.00000000E 03

  END OF READ,
```

```
RUN NO. CHK001                                  DATE 031176                                          PAGE NO.   5
EP  1                                          RUN BY E J KUMAR

         STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
         20 DOF LONGITUDINAL ROD      2 SUBSTRUCTURES

     LAM2
     (    1 X  10 )          (  2)        (  3)        (  4)        (  5)        (  6)        (  7)        (  8)        (  9)        ( 10)
     1     1 -3.9798E-05  1.9577E 02  7.6393E 02  1.6489E 03  2.7639E 03  4.0000E 03  5.2361E 03  6.3511E 03  7.2361E 03  7.8042E 03

     OMG2
     (    1 X  10 )          (  2)        (  3)        (  4)        (  5)        (  6)        (  7)        (  8)        (  9)        ( 10)
     1     1  6.3085E-03  1.3992E 01  2.7639E 01  4.0606E 01  5.2573E 01  6.3246E 01  7.2361E 01  7.9694E 01  8.5065E 01  8.8342E 01

     CPS2
     (    1 X  10 )          (  2)        (  3)        (  4)        (  5)        (  6)        (  7)        (  8)        (  9)        ( 10)
     1     1  1.0040E-03  2.2269E 00  4.3989E 00  6.4627E 00  8.3673E 00  1.0066E 01  1.1517E 01  1.2684E 01  1.3539E 01  1.4060E 01
```

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD 2 SUBSTRUCTURES

PHY2
(10 X 10)

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	1	3,1623E-01	4,4171E-01	4,2533E-01	3,9847E-01	3,6180E-01	3,1623E-01	2,6287E-01	2,0303E-01	1,3820E-01	6,9960E-02
2	1	3,1623E-01	3,9847E-01	2,6287E-01	6,9960E-02	-1,3820E-01	-3,1623E-01	-4,2533E-01	-4,4171E-01	-3,6180E-01	-2,0303E-01
3	1	3,1623E-01	3,1623E-01	3,1425E-08	-3,1623E-01	-4,4721E-01	-3,1623E-01	-7,3020E-09	3,1623E-01	4,4721E-01	3,1623E-01
4	1	3,1623E-01	2,0303E-01	-2,6287E-01	-4,4171E-01	-1,3820E-01	3,1623E-01	4,2533E-01	6,9960E-02	-3,6180E-01	-3,9847E-01
5	1	3,1623E-01	6,9960E-02	-4,2533E-01	-2,0303E-01	3,6180E-01	3,1623E-01	-2,6287E-01	-3,9847E-01	1,3820E-01	4,4171E-01
6	1	3,1623E-01	-6,9960E-02	-4,2533E-01	2,0303E-01	3,6180E-01	-3,1623E-01	-2,6287E-01	3,9847E-01	1,3820E-01	-4,4171E-01
7	1	3,1623E-01	-2,0303E-01	-2,6287E-01	4,4171E-01	-1,3820E-01	-3,1623E-01	4,2533E-01	-6,9960E-02	-3,6180E-01	3,9847E-01
8	1	3,1623E-01	-3,1623E-01	1,6953E-09	3,1623E-01	-4,4721E-01	3,1623E-01	-5,1081E-08	-3,1623E-01	4,4221E-01	-3,1623E-01
9	1	3,1623E-01	-3,9847E-01	2,6287E-01	-6,9960E-02	-1,3820E-01	3,1623E-01	-4,2533E-01	4,4171E-01	-3,6180E-01	2,0303E-01
10	1	3,1623E-01	-4,4171E-01	4,2533E-01	-3,9847E-01	3,6180E-01	-3,1623E-01	2,6287E-01	-2,0303E-01	1,3820E-01	-6,9960E-02

RUN NO. CHK001 DATE 031176 PAGE NO. 7
EP 1 RUN BY E J KUMAR

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD 2 SUBSTRUCTURES

```
SUBSTRUCTURES READ INTO PROGRAM
(   1 X   2 )      ( 2) ( 3) ( 4) ( 5) ( 6) ( 7) ( 8) ( 9) (10) (11) (12) (13) (14) (15) (16) (17) (18) (19) (20)

  1    1           1    2
```

ENTRY POINT 1 HAS BEEN COMPLETED.

```
COUPLING CHECK CASE FROM ENTRY POINT 1
GITUDINAL ROD     2 SUBSTRUCTURES

            2.

            1.
.   IEND  =          0.

1           =1
NTR2A

1           =1
NTR2B

CPL     (   2 X   2 )             COUPLING SPRING STIFFNESS MATRIX            0

0000E 03  -2.00000000E 03
0000E 03   2.00000000E 03
```

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD 2 SUBSTRUCTURES

CONNECTIVITY FOR COUPLED SUBSTRUCTURES

(20 X 20)			(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1	1	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ENTRY POINT 2 HAS BEEN COMPLETED,

```
        STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
        20 DOF LONGITUDINAL ROD     2 SUBSTRUCTURES

NAMELIST    ENTR3
IV     (1)
     1        1         2         8         2         2         8
END   NAMELIST    ENTR3

SUBSTRUCTURE =   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
NKEPT        =   2   2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
NREDUCED     =   8   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

TOTAL DOF KEPT =    4        TOTAL DOF REDUCED =   16

                    ENTRY POINT    3    HAS BEEN COMPLETED.
```

```
STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD     2 SUBSTRUCTURES

NAMELIST   ENTR4
LAMDAO=   0,
$ END
```

```
        STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
        20 DOF LONGITUDINAL ROD      2 SUBSTRUCTURES

    LAMSYS (EIGENVALUES)
    (   1 X   4 )         (  2)        (  3)        (  4)        (
    1     1  1.2331E 01  1.1057E 02  3.0615E 02  6.5858E 02

    OMEGA  (RAD/SEC)
    (   1 X   4 )         (  2)        (  3)        (  4)        (
    1     1  3.5115E 00  1.0515E 01  1.7497E 01  2.5663E 01

    FCPS   (HZ)
    (   1 X   4 )         (  2)        (  3)        (  4)        (
    1     1  5.5887E-01  1.6736E 00  2.7848E 00  4.0845E 00
```

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD   2 SUBSTRUCTURES

ENTRY POINT   4   HAS BEEN COMPLETED.

```
STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD     2 SUBSTRUCTURES

NAMELIST    ENTRS
NMODES=          4,   MD1    =          1,   MD2    =          4,   PF1    =          1,   PF2    =          4,
GMIN  =   0.
NTAPE =          0,   KMODES=           4,   LIST   =          0,
$ END
```

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD 2 SUBSTRUCTURES

SYSTEM DOF TABLE FOR PARTICIPATION FACTORS

SUBSTRUCTURE	MODES	SYSTEM DOF
1	1 TO 2	1 TO 2
1	3 TO 10	5 TO 12
2	1 TO 2	3 TO 4
2	3 TO 10	13 TO 20

```
STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD      2 SUBSTRUCTURES

OUTPUT MATRIX PF1      (   1 X  20 )

             ( 1)       ( 2)       ( 3)       ( 4)       ( 5)       ( 6)       ( 7)       ( 8)       ( 9)       (10)
  1    1   4,2409E-01 3,6045E-02 9,0055E-01-8,4553E-02 1.2456E-02 6,1665E-03 3.5596E-03 2,2177E-03 1.4190E-03 8,8522E-04
  1   11   4,8749E-04 1,5587E-04-1,9645E-02-8,5355E-03-4.6234E-03-2,7928E-03-1,7732E-03-1,1291E-03-6,7455E-04-3,1662E-04
END OF WRITE,

OUTPUT MATRIX PF2      (   1 X  20 )

             ( 1)       ( 2)       ( 3)       ( 4)       ( 5)       ( 6)       ( 7)       ( 8)       ( 9)       (10)
  1    1   7,6495E-01-1,4061E-01-3,0092E-01 5,4548E-01-3.9138E-02-1,9376E-02-1.1185E-02-6,9681E-03-4.4588E-03-2,7814E-03
  1   11  -1,5317E-03-4,8976E-04 6,1788E-02 2,6819E-02 1.4527E-02 8,7736E-03 5,5714E-03 3,5477E-03 2.1195E-03 9,9484E-04
END OF WRITE,

OUTPUT MATRIX PF3      (   1 X  20 )

             ( 1)       ( 2)       ( 3)       ( 4)       ( 5)       ( 6)       ( 7)       ( 8)       ( 9)       (10)
  1    1   3,0637E-01-5,9136E-01-1,8235E-01-7,0646E-01-7.2706E-02-3,5994E-02-2.0777E-02-1,2945E-02-8.2830E-03-5,1670E-03
  1   11  -2,8495E-03-9,0983E-04 1,1478E-01 4,9822E-02 2.6987E-02 1,6299E-02 1.0350E-02 6,5905E-03 3.9373E-03 1,8481E-03
END OF WRITE,

OUTPUT MATRIX PF4      (   1 X  20 )

             ( 1)       ( 2)       ( 3)       ( 4)       ( 5)       ( 6)       ( 7)       ( 8)       ( 9)       (10)
  1    1   2,8307E-01 7,5577E-01-1,8577E-01-3,6925E-01-1,9748E-01-9,7763E-02-5,6434E-02-3,5159E-02-2.2497E-02-1,4034E-02
  1   11  -7,7286E-03-2,4712E-03 3,1176E-01 1,3532E-01 7,3299E-02 4,4269E-02 2,8112E-02 1,7901E-02 1.0694E-02 5,0196E-03
END OF WRITE,
```

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD 2 SUBSTRUCTURES

SUBSTRUCTURE IDENTIFICATION TABLE

SUBSTRUCTURE	NSUBS	PHY(I)
1	1	1 TO 1
2	1	2 TO 2

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD 2 SUBSTRUCTURES

PHYS1

(10 X	4)	(2)	(3)	(4)
1 1	2.1464E-01	2.4881E-01	-1.7831E-01	2.9803E-01
2 1	1.9570E-01	2.8771E-01	-6.2514E-02	3.9466E-01
3 1	1.7570E-01	3.0988E-01	5.8606E-02	3.3656E-01
4 1	1.5459E-01	3.1516E-01	1.7201E-01	1.7497E-01
5 1	1.3242E-01	3.0359E-01	2.6207E-01	-2.6824E-02
6 1	1.0948E-01	2.7569E-01	3.1428E-01	-2.0649E-01
7 1	8.5826E-02	2.3264E-01	3.1889E-01	-3.1519E-01
8 1	6.1669E-02	1.7650E-01	2.7352E-01	-3.2695E-01
9 1	3.7146E-02	1.1021E-01	1.8425E-01	-2.4290E-01
10 1	1.2406E-02	3.7472E-02	6.4967E-02	-8.9395E-02

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD 2 SUBSTRUCTURES

PHYS2
(10 X 4)

		(1)	(2)	(3)	(4)
1	1	2.3230E-01	1.9333E-01	-2.8139E-01	1.8050E-02
2	1	2.4840E-01	1.3063E-01	-3.2350E-01	-1.6334E-01
3	1	2.6293E-01	6.1967E-02	-3.0961E-01	-2.5305E-01
4	1	2.7584E-01	-1.0278E-02	-2.4915E-01	-2.6423E-01
5	1	2.8709E-01	-8.2830E-02	-1.5589E-01	-2.1496E-01
6	1	2.9660E-01	-1.5167E-01	-4.2702E-02	-1.2651E-01
7	1	3.0431E-01	-2.1333E-01	7.1972E-02	-2.1249E-02
8	1	3.1016E-01	-2.6330E-01	1.7367E-01	7.9566E-02
9	1	3.1409E-01	-2.9875E-01	2.4941E-01	1.5784E-01
10	1	3.1607E-01	-3.1706E-01	2.8976E-01	2.0043E-01

STIFFNESS COUPLING CHECK CASE FROM ENTRY POINT 1
20 DOF LONGITUDINAL ROD 2 SUBSTRUCTURES

ENTRY POINT 5 HAS BEEN COMPLETED.

TIME SHEET

```
CURRENT TIME OF DAY          =     10,947209
```

END OF INPUT DATA HAS BEEN REACHED.